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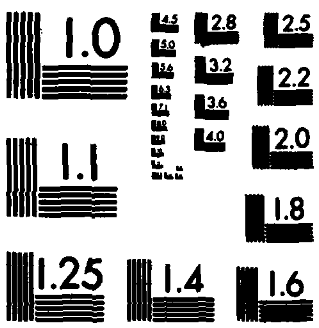

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AD-A146 535

Use of Computer Program HEC-5 for Water Supply Analysis

by

Richard J. Hayes

Bill S. Eichert

Technical Paper No. 101
August 1984

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Paper No. 101	2. GOVT ACCESSION NO. A146535	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) USE OF COMPUTER PROGRAM HEC-5 FOR WATER SUPPLY ANALYSIS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard J. Hayes and Bill S. Eichert		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Corps of Engineers The Hydrologic Engineering Center 609 Second Street, Davis, CA 95616		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE August 1984
		13. NUMBER OF PAGES 7 pages
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution is unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Twentieth Annual American Water Resources Association Conference, Washington, D.C., August 14, 1984

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In addition to Corps of Engineers applications, the HEC-5 program has been widely applied by other federal agencies, state water resource agencies and domestic and foreign engineering firms. The 1979 and 1982 versions of HEC-5 will be replaced by the soon to be released 1984 version which will provide improved analysis capabilities for water supply, hydropower, and flood control simulations. In addition, the 1984 version will incorporate code modifications which simplify and modularize the code in order to minimize program maintenance, enhance readability, facilitate program improvements and enhance hardware adaptability.

USE OF COMPUTER PROGRAM HEC-5
FOR
WATER SUPPLY ANALYSIS[1]

Richard J. Hayes and Bill S. Eichert[2]

ABSTRACT

Computer program HEC-5, "Simulation of Flood Control and Conservation Systems," has extensive capabilities for the analysis of water supply systems. HEC-5, developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center in Davis, California, is the Corps principal reservoir simulation model. Water supply analysis capabilities include options for period-of-record optimization of water supply storage and yields, conservation operation which distinguishes between desired and required (essential) water supply demands, provisions for monthly or seasonally varying reservoir operation levels (rule curves), a variety of water supply diversions, and consideration of evaporation. Multipurpose, multireservoir systems may be simulated with hourly, daily, weekly or monthly simulation intervals.

In addition to Corps of Engineers applications, the HEC-5 program has been widely applied by other federal agencies, state water resource agencies and domestic and foreign engineering firms. The 1979 and 1982 versions of HEC-5 will be replaced by the soon to be released 1984 version which will provide improved analysis capabilities for water supply, hydropower, and flood control simulations. In addition, the 1984 version will incorporate code modifications which simplify and modularize the code in order to minimize program maintenance, enhance readability, facilitate program improvements and enhance hardware adaptability.

INTRODUCTION

Computer program HEC-5 "Simulation of Flood Control and Conservation Systems," (HEC, 1982) has been developed at the Hydrologic Engineering Center (HEC) by Bill S. Eichert, Director of the HEC. HEC-5 has evolved during the eleven years (1973-1984) of its development from a single purpose, single flood event simulation model to a comprehensive multiple purpose, period-of-record simulation model which has become the principal reservoir system analysis program of the Corps of Engineers. The HEC-5 development has expanded in that period in response to specific needs of the Corps of Engineers. The initial development focused on the simulation of flood control reservoir systems during individual floods and the determination of flood damages. During the latter seventies, in response to the Corps leadership role in the National Hydropower Study, enhanced capabilities for the simulation and sizing of hydropower facilities were added. During the past two years, in response to increased Corps interest in the solution of water supply problems, there have been a series of program improvements directly related to water supply analysis. In addition to expected further development for water supply analysis, planned program development in the next two years includes: continued efforts to modernize and improve program code to ease program maintenance, efficiency and adaptability; addition of more detailed hydropower design related options; and application and testing of the water quality version HEC-5Q (HEC, 1982) of the program.

[1]Presented at the Twentieth Annual American Water Resources Association Conference, Washington, D. C., August 14, 1984.

[2]Respectively, Hydraulic Engineer and Director, U.S. Army Corps of Engineers, The Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616

HEC-5 is currently being applied by the HEC in two on-going Corps of Engineers water supply investigations. These studies not only provide needed assistance to the local Corps District office, but also provide the HEC with an opportunity to test program developments in a variety of field conditions. The HEC also is currently providing assistance to other agencies in the application of HEC-5 to water supply analysis, most notably, the U.S. Bureau of Reclamation and the United Nations Development Program in India.

OVERVEIW OF HEC-5 CAPABILITIES

HEC-5 is capable of simulating the operation of systems of reservoirs for both flood control and conservation requirements. Detailed information on the program's capabilities, as well as example applications is contained in the HEC-5 Users Manual (HEC, 1982); a brief listing of HEC-5 capabilities is also displayed in the accompanying Table 1. Reservoir operation for conservation can include hydropower and water supply releases which consider the availability of reservoir storage. Releases can be based on requirements at the reservoir or at any number of downstream control points. Flood control releases for downstream control points include the impact of routing as well as intervening local flows. To provide realistic simulations, a forecast time (for downstream flows) and a contingency factor may be specified. Five hydrologic routing methods including Muskingum and Modified Puls are available for use with HEC-5.

The allocation of reservoir storage or levels (see Figure 1) for flood control and conservation storage can vary monthly or on a seasonal basis. The basic operation of the program, while a reservoir is above the top of the conservation storage (i.e., in the flood control storage zone), is to maximize reservoir releases without causing flooding at downstream locations until such a time as the reservoir is lowered to the top of the conservation zone.

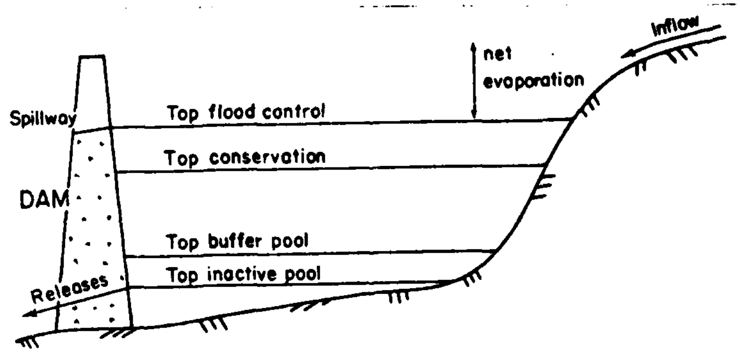

Fig. 1 Reservoir Operating Levels

Flood control releases consider: capacities of spillways and other outlet works; rates of change; safe channel capacities at the dam and at designated downstream control points; the effects of routing; releases from other reservoirs; local uncontrolled flows; forecasting; contingencies and operational priorities.

During time periods when a reservoir level is below the top of the conservation level the basic operation is based on minimizing releases while providing for all conservation demands until such a time as the reservoir must make flood control releases. Within the conservation storage zone is another storage level termed the buffer level. Releases made while storage is below the buffer level are only made to satisfy essential water supply requirements (called required flows in HEC-5 output). Conservation releases consider: specified flow requirements at the dam and at designated downstream control points; availability of conservation storage (i.e., <u>desired</u> flows when storage is sufficient and <u>required</u> flows when main conservation storage is depleted); hydropower generation requirements; downstream diversions; releases from other reservoirs; routing effects; local uncontrolled flows;

GENERAL CAPABILITIES

Any configuration of reservoir system (the upstream most locations must be reservoirs)

Operation of gated reservoir outlets based on downstream flows considering routing effects.

Flexible output - user designed, sequential, annual summaries, flood summaries, etc.

Hydrologic routing methods.

Forecasting ability and contingency factor which limit operation efficiency.

User override of reservoir releases.

Variable time steps (hourly, daily, weekly, monthly or mixture).

Capable of period-of-record simulations, any number of floods - unlimited number of time periods.

Inflows may be incremental or cumulative, and average or end of period.

Seasonal Reservoir operation (rule curves)

FLOOD CONTROL OPERATION

Flood damages or average annual damage - annual peaks or seasonal and duration effects.

Flood control system operation.

Emergency Gate Regulation.

Variable channel capacity.

HYDROPOWER OPERATION

Optimization of installed capacity or monthly energy production based on firm energy approach.

Energy demands: system and at site (monthly, daily, hourly) or plant factor vs percent conservation storage.

Tailwater: rating curve, downstream reservoir or block loading.

Peaking capability.

Pumped storage simulation.

WATER SUPPLY OPERATION

Optimization of reservoir storage, yields and diversions.

Optimization of downstream control point water supply demands.

Specification of required and desired flow goals at reservoirs and at control points.

Diversions to upstream or downstream locations.

Balanced reservoir levels for operation of reservoir systems.

WATER QUALITY OPERATION (ONLY AVAILABLE IN HEC-5Q VERSION)

Multi-level gate operation.

Flow alteration.

Temperature analysis.

3 nonconservative parameters.

3 conservative parameters.

Phytoplankton analysis.

Daily and monthly time steps.

forecasting; contingencies; and operational priorities. Optimization studies can also be accomplished with HEC-5 to determine reservoir storages, water supply yields, diversions, and hydropower capacities and energy production.

Time series data (i.e., inflows) may be specified with time increments ranging from one hour to one month. Any number of flow periods may be specified, and time intervals may be varied within a given simulation. Inflow data may be either cumulative or incremental and either average or end of period values may be specified. Metric or English units may be specified.

HEC-5 WATER SUPPLY ANALYSIS CAPABILITIES

Reservoir operation to provide water supplies to meet downstream low flow requirements such as municipal and industrial, irrigation, navigation, fishery maintenance, recreation or water quality needs may be simulated with HEC-5. Detailed information on the application of HEC-5 for the simulation of water supply reservoirs is contained in Draft Training Document 20, Water Supply Simulation Using HEC-5 (HEC, 1983). Two types of low flow releases may be specified: minimum desired flows and minimum required flows. Reservoirs operate to release flows to satisfy minimum desired flow criteria when operating in the conservation storage zone while above the buffer level. In HEC-5 the buffer level represents the storage level at which a transition is made from normal water supply operation (minimum desired flows) to an operation for water supply (minimum required flows) during drought conditions. Minimum desired and required flows may be specified at reservoirs or non-reservoir control points as constant values, as flows which vary monthly or as minimum flows which vary period by period.

Water supply diversions, often primary features in typical water supply systems, may be included in HEC-5 simulation models. HEC-5 diversion options include constant, monthly varying, period varying, as well as diversions which are functions of stream flow, reservoir storage, or available pumping energy. Diversions may be made at both reservoirs and non-reservoir control points and may return to the system at upstream or downstream locations. Routing effects and percent of flow returning to the system can also be specified.

During water supply reservoir planning studies it is usually desirable to determine the minimum conservation storage based on a flow sequence (usually the historic period-of-record) which will be required to meet projected water supply requirements. The yield problem, in which a fixed amount of conservation storage is available and it is desired to determine the reliable water supply yield, is also typically addressed in water supply planning studies. Solutions to these two planning problems can be derived with the HEC-5 optimization options.

The HEC-5 optimization solution process employs iterative simulations using a monthly time step and user-defined allowable error criteria. In order to reduce the number of period-of-record simulations to a minimum, the program uses either a user supplied or an HEC-derived rule of thumb approach to define a critical period. When the optimization process has determined a minimum storage or reservoir yield, using the program-determined critical period that satisfies the user-supplied error criteria, the program will then check the results of the optimization process by simulating the optimized storage or yield with the entire period-of-record. The program's optimization option can be directed to repeat the entire sequence (critical period determination; optimization; period-of-record simulation) up to two more times if required.

The optimization for reservoir yield can be conducted for both the minimum desired flow (using the conservation pool above the buffer level) and the minimum required flow (using the entire conservation storage). Diversion schedules may also be optimized by the program. The 1984 version of HEC-5 provides for the optimization of yields (minimum desired and required flows) and diversions at downstream locations with consideration for local flows. Earlier versions restrict the optimization to yields and diversions at the dam. Currently, reservoirs may only be optimized singly. It is anticipated that with continued interest by the various Corps District offices, the HEC-5 optimization capability will be extended to provide the ability to optimize yields for multiple reservoir systems.

USE OF HEC-5 IN WATER SUPPLY STUDIES

The HEC has recently completed a comprehensive application of HEC-5 for analysis of existing and proposed reservoirs in the Lehigh River Basin, Pennsylvania, for the Philadelphia District, U.S. Army Corps of Engineers. The primary emphasis of the study was the analysis of reallocation of flood control storage to hydropower and water supply storage.

The HEC developed four sets of HEC-5 models for analysis of the various reservoir alternatives. Ten alternative reservoir systems were analyzed with a daily simulation interval for water supply and hydropower production. Simulations were made with a 50-year period of mean daily natural flows. The 50-year daily simulation models were kept as simple as possible in order to keep execution times on the HEC HARRIS 500 computer to a minimum. A schematic of the HEC-5 daily simulation model for the Lehigh Basin is shown in Figure 2. In contrast, the HEC-5 two-hour flood simulation model of the Lehigh Basin for a nine-day flood event required operation for thirty-one control points (reservoirs and damage centers).

Reservoir yields for selected conservation storages at the existing and proposed reservoirs were determined with a set of HEC-5 models using a 50-year period of monthly flows. Additional hydropower simulations were made with a one-hour simulation interval to determine the performance of proposed pumped storage hydropower alternatives.

The HEC is currently applying HEC-5 in two ongoing Corps of Engineers water supply studies in Georgia and California. HEC-5 is also being applied with assistance from the HEC in two USBR studies in California and Arizona and by the United Nations Development Program personnel in India.

SUMMARY

HEC-5 is a widely utilized U.S. Army Corps of Engineers reservoir system simulation model which has broad water supply analysis capabilities. The program source code, documentation, and applications assistance are available from the Hydrologic Engineering Center, 609 Second Street, Davis, California, 95616. It is anticipated that a new version of HEC-5 which incorporates water supply analysis and hardware adaptability enhancements will be released in the fall of 1984.

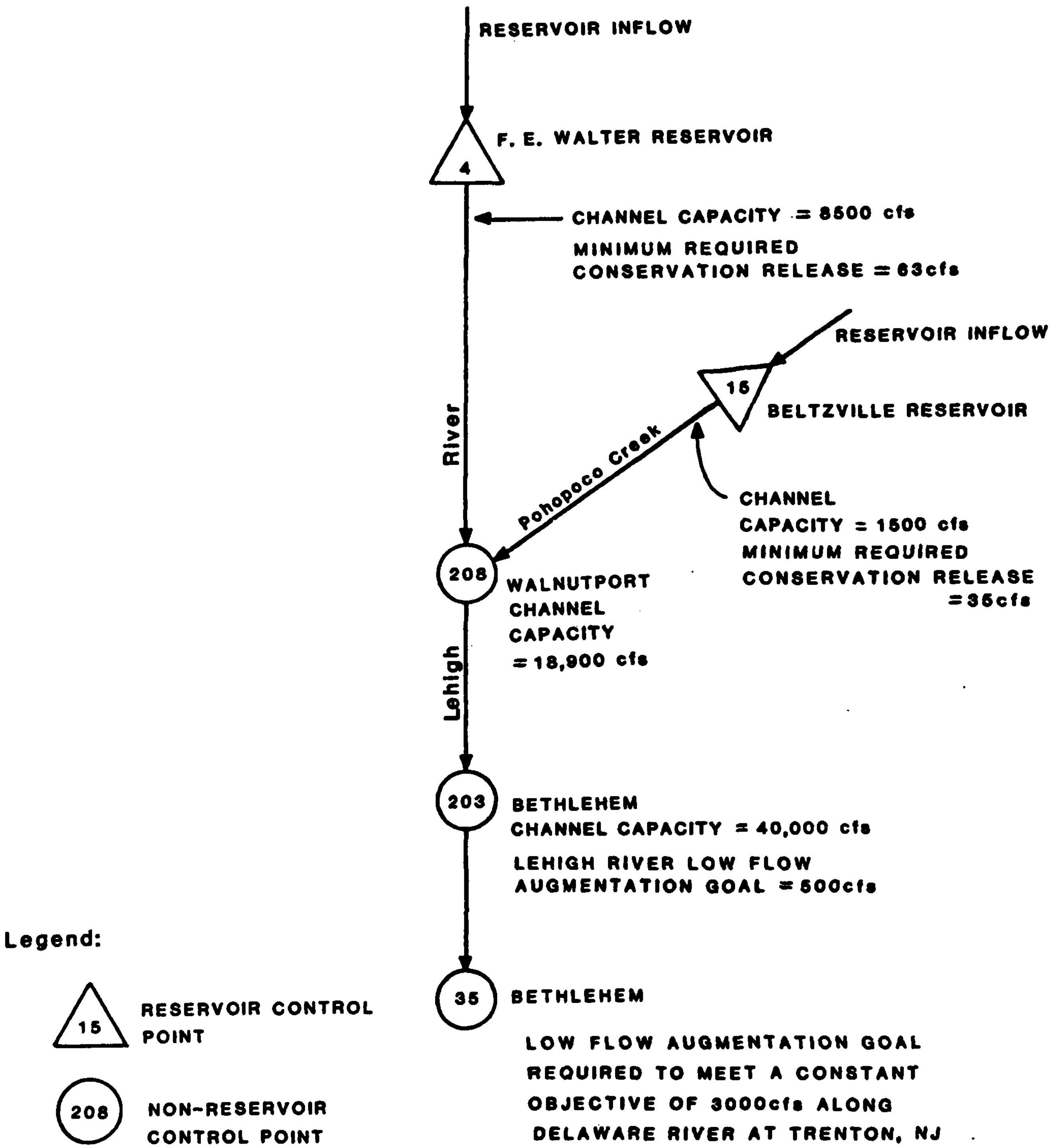

Figure 2

LEHIGH RIVER BASIN HEC-5 DAILY OPERATION MODEL - SCHEMATIC DIAGRAM

REFERENCES

1. HEC-5, Simulation of Flood Control and Conservation Systems, Computer Program, U.S. Army Corps of Engineers, The Hydrologic Engineer Center, April 1982.

2. HEC-5Q, Simulation of Flood Control and Conservation Systems (Including Water Quality Analysis), Computer Program, U.S. Army Corps of Engineers, The Hydrologic Engineering Center, October 1982.

3. HEC-5, Simulation of Flood Control and Conservation Systems, Users Manual, U.S. Army Corps of Engineers, The Hydrologic Engineering Center, April 1982.

4. Training Document No. 20 (Draft), Water Supply Simulation Using HEC-5, U.S. Army Corps of Engineers, The Hydrologic Engineering Center, July 1983.

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14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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TECHNICAL PAPERS (TP)

Technical papers are written by the staff of the HEC, sometimes in collaboration with persons from other organizations, for presentation at various conferences, meetings, seminars and other professional gatherings.

This listing includes publications starting in 1978.

HEC NUMBER	TITLE	HEC PRICE	NTIS NUMBER
		$2.00 Each	
TP-52	Potential Use of Digital Computer Ground Water Models, D. L. Gundlach, Apr 78, 38 pp.		ADA-106 251
TP-53	Development of Generalized Free Surface Flow Models Using Finite Element Techniques, D. M. Gee and R. C. MacArthur, Jul 78, 21 pp.		ADA-106 252
TP-54	Adjustment of Peak Discharge Rates for Urbanization, D. L. Gundlach, Sep 78, 7 pp.		ADA-106 253
TP-55	The Development and Servicing of Spatial Data Management Techniques in the Corps of Engineers, R. P. Webb and D. W. Davis, Jul 78, 26 pp.		ADA-106 254
TP-56	Experiences of the Hydrologic Engineering Center in Maintaining Widely Used Hydrologic and Water Resource Computer Models, B. S. Eichert, Nov 78, 16 pp.		ADA-106 255
TP-57	Flood Damage Assessments Using Spatial Data Management Techniques, D. W. Davis and R. P. Webb, May 78, 27 pp.		ADA-106 256
TP-58	A Model for Evaluating Runoff-Quality in Metropolitan Master Planning, L. A. Roesner, H. M. Nichandros, R. P. Shubinski, A. D. Feldman, J. W. Abbott, and A. O. Friedland, Apr 72, 81 pp.		ADA-106 257

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TP-59	Testing of Several Runoff Models on an Urban Watershed, J. Abbott, Oct 78, 53 pp.		ADA-106 258
TP-60	Operational Simulation of a Reservoir System with Pumped Storage, G. F. McMahon, V. R. Bonner and B. S. Eichert, Feb 79, 32 pp.		ADA-106 259
TP-61	Technical Factors in Small Hydropower Planning, D. W. Davis, Feb 79, 35 pp.		ADA-109 757
TP-62	Flood Hydrograph and Peak Flow Frequency Analysis, A. D. Feldman, Mar 79 21 pp.		ADA-109 758
TP-63	HEC Contribution to Reservoir System Operation, B. S. Eichert and V. R. Bonner, Aug 79, 28 pp.		ADA-109 759
TP-64	Determining Peak-Discharge Frequencies in an Urbanizing Watershed: A Case Study, S. F. Daly and J. C. Peters, Jul 79, 15 pp.		ADA-109 760
TP-65	Feasibility Analysis in Small Hydropower Planning, D. W. Davis and B. W. Smith, Aug 79, 20 pp.		ADA-109 761
TP-66	Reservoir Storage Determination by Computer Simulation of Flood Control and Conservation Systems, B. S. Eichert, Oct 79, 10 pp.		ADA-109 762
TP-67	Hydrologic Land Use Classification Using LANDSAT, R. J. Cermak, A. D. Feldman and R. P. Webb, Oct 79, 26 pp.		ADA-109 763
TP-68	Interactive Nonstructural Flood-Control Plannng, D. T. Ford, Jun 80, 12 pp.		ADA-109 764

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HEC NUMBER	TITLE	HEC PRICE	NTIS NUMBER
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TP-69	Critical Water Surface by Minimum Specific Energy Using the Parabolic Method, B. S. Eichert, 1969, 15 pp.		ADA-951 599
TP-70	Corps of Engineers Experience with Automatic Calibration of a Precipitation-Runoff Model, D. T. Ford, E. C. Morris, and A. D. Feldman, May 80, 12 pp.		ADA-109 765
TP-71	Determination of Land Use from Satellite Imagery for Input to Hydrologic Models, R. P. Webb, R. Cermak, and A. D. Feldman, Apr 80, 18 pp.		ADA-109 766
TP-72	Application of the Finite Element Method to Vertically Stratified Hydrodynamic Flow and Water Quality, R. C. MacArthur and W. R. Norton, May 80, 12 pp.		ADA-109 767
TP-73	Flood Mitigation Planning Using HEC-SAM, D. W. Davis, Jun 80, 17 pp.		ADA-109 756
TP-74	Hydrographs by Single Linear Reservoir Model, J. T. Pederson, J. C. Peters, and O. J. Helweg, May 80, 17 pp.		ADA-109 768
TP-75	HEC Activities in Reservoir Analysis, V. R. Bonner, Jun 80, 10 pp.		ADA-109 769
TP-76	Institutional Support of Water Resource Models, J. C. Peters, May 80, 23 pp.		ADA-109 770
TP-77	Investigation of Soil Conservation Service Urban Hydrology Techniques, D. G. Altman, W. H. Espey, Jr. and A. D. Feldman, May 80, 14 pp.		ADA-109 771
TP-78	Potential for Increasing the Output of Existing Hydroelectric Plants, D. W. Davis and J. J. Buckley, Jun 81, 20 pp.		ADA-109 772

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TP-79	Potential Energy and Capacity Gains from Flood Control Storage Reallocation at Existing U. S. Hydropower Reservoirs, B. S. Eichert and V. R. Bonner, Jun 81, 18 pp.		ADA-109 787
TP-80	Use of Non-Sequential Techniques in the Analysis of Power Potential at Storage Projects, G. M. Franc, Jun 81, 18 pp.		ADA-109 788
TP-81	Data Management Systems for Water Resources Planning, D. W. Davis, Aug 81, 12 pp.		ADA-114 650
TP-82	The New HEC-1 Flood Hydrograph Package, A. D. Feldman, P. B. Ely and D. M. Goldman, May 81, 28 pp.		ADA-114 360
TP-83	River and Reservoir Systems Water Quality Modeling Capability, R. G. Willey, Apr 82, 15 pp.		ADA-114 192
TP-84	Generalized Real-Time Flood Control System Model, B. S. Eichert and A. F. Pabst, Apr 82, 18 pp.		ADA-114 359
TP-85	Operation Policy Analysis: Sam Rayburn Reservoir, D. T. Ford, R. Garland and C. Sullivan, Oct 81, 16 pp.		ADA-123 526
TP-86	Training the Practitioner: The Hydrologic Engineering Center Program, W. K. Johnson, Oct 81, 20 pp.		ADA-123 568
TP-87	Documentation Needs for Water Resources Models, W. K. Johnson, Aug 82, 16 pp.		ADA-123 558
TP-88	Reservoir System Regulation for Water Quality Control, R.G. Willey, Mar 83, 18 pp.		ADA-130 829
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TP-90	Calibration, Verification and Application of a Two-Dimensional Flow Model, D. M. Gee, Sep 83, 6 pp.		ADA-135 668
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TP-92	Hydrologic Engineering Center Planning Models D. T. Ford and D. W. Davis, Dec 83, 17 pp.		ADA-139 010
TP-93	Flood Routing Through A Flat, Complex Floodplain Using A One-Dimensional Unsteady Flow Computer Program, J. C. Peters, Dec 83, 8 pp.		ADA-139 011
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TP-99	Reservoir System Analysis for Water Quality, J. H. Duke, D. J. Smith and R. G. Willey, Aug 84, 27 pp.		

TECHNICAL PAPERS (TP)(Continued)

HEC NUMBER	TITLE	HEC PRICE	NTIS NUMBER
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